

SEABIRDS

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OVERVIEW

Resident and migratory populations of over 75 legally-protected seabird species depend upon habitats and food webs in the California Current Large Marine Ecosystem. Seabirds provide one of the most publically-visible indicators of ecosystem productivity and health.

EXECUTIVE SUMMARY

The Integrated Ecosystem Assessment (IEA) for the California Current Large Marine Ecosystem (CCLME) explicitly includes seabirds as an ecosystem component because seabirds require CCLME habitats and food webs to maintain healthy populations. The CCLME supports more than 75 species of seabirds, including breeding, non-breeding, and migratory populations. NOAA Fisheries has legal, management, and conservation mandates to understand and protect seabird populations. All seabird species are legally protected by the Migratory Bird Treaty Act (1918). Executive Order 13186 (2001) requires NOAA Fisheries to incorporate migratory birds into Agency planning, address migratory bird concerns, and cooperate with other agencies that have responsibilities for managing or protecting migratory birds. A Memorandum of Understanding between NOAA Fisheries and the US Fish and Wildlife Service addresses areas of joint concern (NMFS 2012). The Endangered Species Act (1973), the Magnuson-Stevens Act (1976), and the US National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (2001) also require NOAA to protect threatened seabirds, conserve seabird habitat, address seabird mortality caused by bycatch in fisheries, and evaluate seabird impact on ESA-listed fishes. Although the United States is not currently a signatory on the Agreement on the Conservation of Albatrosses and Petrels treaty (2004), NOAA regularly sends delegates to these international meetings. In response to these mandates and responsibilities, NOAA Fisheries implements a National Seabird Program that specifically calls for the use of seabird indicators to improve ecosystem-based science and management. Inclusion of seabirds in the 2012 IEA is not only necessary for advancement of the IEA process, but also supports several other national-level priorities for science and stewardship of marine resources.

INDICATORS

Through a rigorous selection process, we chose four key seabird indicators from an initial list of 12 indicators. The final indicators are:

- habitat use at sea
- annual reproductive performance
- mortality rates and agents
- diet composition

Information gaps identified include (1) winter data for density/habitat use at sea and diet in all domains of the CCLME; (2) very short, and potential loss of, time series data for habitat use at sea, annual reproductive performance, and diet in Oregon/Washington (northern domain of CCLME); and (3) diet information for non-breeding birds and adult birds in all domains.

STATUS

Seabird indicator data are collected independently by different institutions or individuals, making data synthesis challenging. The 2012 IEA process identified at least 19 sources of contemporary data potentially available from all three CCLME biogeographic domains.

Although it is beyond the scope of 2012 IEA to synthesize all potential 19 seabird indicator data sets, we examined trends in sample data sets from the northern and southern domains of the CCLME. Comparisons of preliminary trends from two common piscivores and one common planktivore showed an increasing trend for one piscivore (common murre, *Uria aalge*); a stable trend for another piscivore (sooty shearwater, *Puffinus griseus*) and a slight decreasing trend for the planktivore (Cassin's auklet, *Ptychoramphus aleuticus*).

Seabird data sets are funded, collected by, and maintained by many different entities (NOAA and non-NOAA); cooperation between these groups and compilation of seabird data is time-intensive. We recommend that future work support (1) a comprehensive synthesis of representative indicator data sets for each biogeographic region of the CCLME and (2) a risk analysis for seabirds based on that synthesis as we were unable to accomplish this task with available resources presently

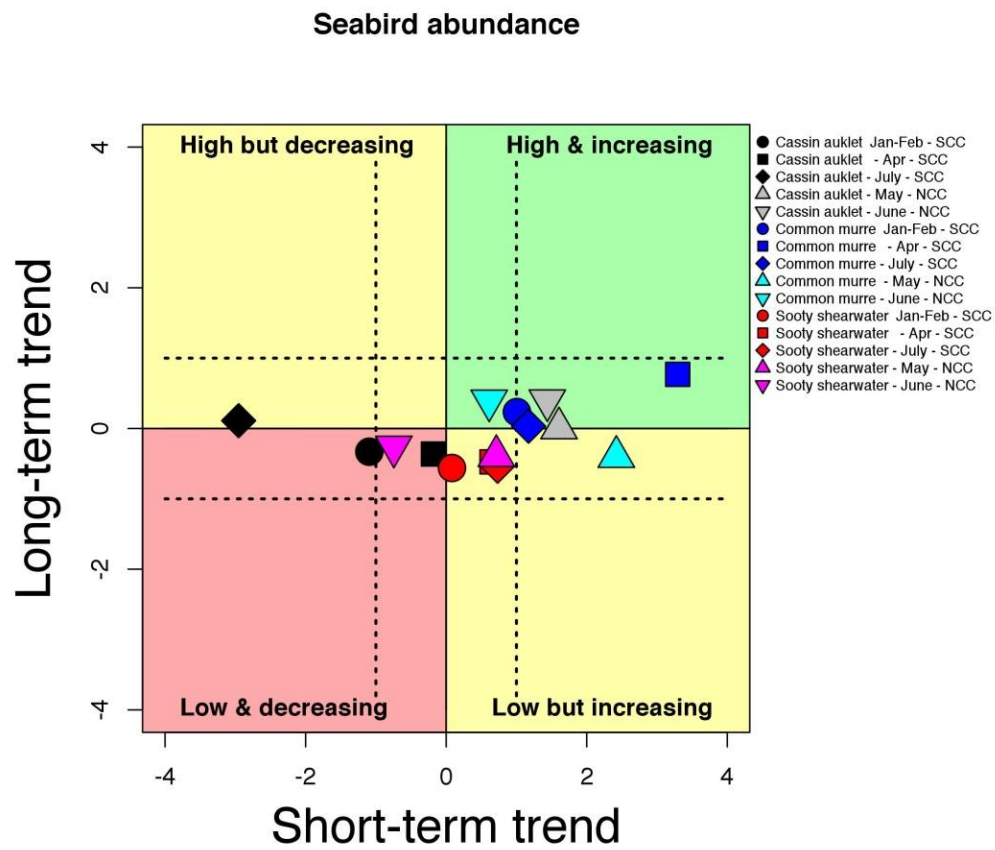


Figure SBX. Quadratic plot of trends in abundance at sea for the two most common piscivores in the CCLME (common murre, sooty shearwater) and one of the common planktivores (Cassin's auklet).

DETAILED REPORT

INDICATOR EVALUATION

BACKGROUND – JUSTIFICATION FOR INCLUSION OF SEABIRD INDICATORS

The Integrated Ecosystem Assessment (IEA) for the California Current Large Marine Ecosystem (CCLME) explicitly includes seabirds as an ecosystem component because seabird species require CCLME habitats and food webs to maintain healthy populations. The CCLME supports more than 75 species of seabirds, including breeding, non-breeding, and migratory populations. NOAA Fisheries has legal, management, and conservation mandates to understand and protect seabird populations. All seabird species are legally protected by the Migratory Bird Treaty Act (1918). Executive Order 13186 (2001) requires NOAA Fisheries to incorporate migratory birds into Agency planning, address migratory bird concerns, and cooperate with other agencies that have responsibilities for managing or protecting migratory birds. A Memorandum of Understanding between the National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service addresses these areas of joint concern (NMFS and USFWS 2012). The Endangered Species Act (1973), the Magnuson-Stevens Act (1976), and the US National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (2001) also require NOAA to protect threatened seabirds, conserve seabird habitat, address seabird mortality caused by bycatch in fisheries, and evaluate seabird impact on ESA-listed fishes. Although the US is not currently a signatory on the Agreement on the Conservation of Albatrosses and Petrels treaty (2004), NOAA regularly sends delegates to these international meetings. In response to all these mandates and responsibilities, NOAA Fisheries implements a National Seabird Program that specifically calls for use of seabird indicators to improve ecosystem-based science and management (<http://www.fakr.noaa.gov/protectedresources/seabirds/national.htm>). That plan specifically calls for the use of seabird indicators to improve ecosystem-based science and management. Therefore, the inclusion of seabirds in the 2012 IEA is not only necessary for advancement of the IEA process, but also supports several other national-level priorities for science and stewardship of marine resources.

INITIAL SELECTION AND EVALUATION OF CANDIDATE INDICATORS.

To evaluate the ecosystem attributes of seabird population size and condition, we required quantitative metrics. Inclusion of measurements of population size and condition for breeding, non-breeding, and migratory birds was considered a requirement.

The Seabird Indicator Team conducted two “brainstorming” sessions with each other, where ideas for all possible quantitative indicators of these seabird-ecosystem attributes were shared. Because we were searching for the best possible indicators, the brainstorming process considered all data types, regardless of whether they had been or are currently being measured in the CCLME. If resources were not limiting and full knowledge of seabird ecosystem attributes were possible, then all 12 indicator types should be measured. However, because resources are limiting, it was necessary to rank the importance indicators as to how well they might represent population attributes. The matrix evaluation process we used to perform this evaluation and ranking is described by Levin and Schwing (2011). This scheme explicitly includes evaluation criteria for

data availability, such as extent of geographic coverage or the existence of time series in the evaluation procedure.

Candidate indicators were nominated because it was agreed each one would be an important element to developing accurate, complete, science-based knowledge of seabird populations in this or any other ecosystem. Group members agreed on 12 possible indicators to evaluate (Table SB1).

Each team member was assigned 4 candidate indicators to evaluate and rank. We used literature reviews (primarily from publications in the last 10 years, including gray literature and reports, using citation databases such as Web of Science and Aquatic Sciences and Fisheries Abstracts) to evaluate each indicator. In cases where a team member was aware of very recent work from our own professional experience or contacts (e.g. new diet studies initiated by state biologists), we contacted the principal investigator to point us to any available but unpublished reports. Because there were 12 candidate indicators, this led to a 204-element evaluation matrix for the entire process.

Every matrix element was assigned one of three color codes and scores:

- **green (score 1.0)** = strong literature support;
- **yellow (score 0.5)** = moderate or limited literature support;
- **red (score 0.0)** = weak or no support, or no data/information available

To ensure team members assigned ranks using very similar evaluation criteria, an initial independent run-through and scoring of one indicator by each team member was conducted. We then discussed the thought process each individual used during their literature search, and how each person assigned scoring of the different consideration factors. Once satisfied that everyone was using similar criteria to assign ranks, individual team members then took responsibility for their assigned literature reviews and remaining matrix evaluations.

TOP RANKED INDICATORS

After individuals completed assigned matrix evaluations, the team shared and discussed matrix results. All indicators were ranked according to the sum of scores in the 17 matrix elements across Primary Considerations (n=5 elements), Data Considerations (n=7 elements), and Other Considerations (n=6 elements). Score assignment was reviewed briefly for each element, so that any new literature information provided by the two members not assigned to score a given matrix element could be considered. Only 12 of 204 cases had matrix element scores that were changed due to newly provided information.

Final rank score sums were sorted in descending rank order.

The Top Three seabird indicators selected, with their cumulative score out of 17 possible, were as follows:

- (1) Indicator: habitat use at sea (Attribute: population size and condition, 15/17)
- (2) Indicator: annual reproductive performance (Attribute: population size and condition, 14.5/17)
- (3) Indicator: mortality rates and agents (Attribute: population condition, 14.5/17)

SEABIRD POPULATION SIZE AND CONDITION – HABITAT USE AT SEA

- (1) ***Habitat use at sea.*** For purposes of this evaluation, the metric “habitat use at sea” includes the use of direct observation of seabirds from ships, land, or aircraft to characterize distribution and abundance at sea; telemetry deployed on individual birds to characterize species ranges, habitat use, and foraging ecology; and individual marks such as leg or wing bands and dyes to quantify individual use of habitat.

THEORETICAL CONSIDERATIONS

An understanding of spatially-explicit habitat use and requirements is an essential component of applying ecosystem-based management to marine spatial planning (Burger and Shaffer 2008, Crowder et al. 2008, Nur et al. 2011). The use of ships, land, and aircraft to collect these data and estimate population size has a long history in peer-reviewed literature (Spear et al. 1992, Clarke et al. 2003), and studies of seabirds at sea in the CCLME are many (Wiens and Scott 1975, Briggs et al. 1985a, b, Briggs et al. 1987, Briggs et al. 1992, Veit et al. 1996, Veit et al. 1997, Mason et al. 2007, Sydeman et al. 2009, Ainley and Hyrenbach 2010). Use of satellite telemetry began in the 1980s, and is becoming common, affordable, and sophisticated with technological improvements over the last two decades (Burger and Shaffer 2008, Hart and Hyrenbach 2009). At-sea information has been used to evaluate and define habitat for managed species, especially for species of conservation concern (Croxall et al. 2012), ESA-listed species requiring critical habitat designations (Piatt et al. 2006, Suryan et al. 2006, Burger and Shaffer 2008), and for sooty shearwaters which are actively managed in New Zealand as a traditional Maori food source (Lyver et al. 1999, Hunter and Caswell 2005, Nevins et al. 2009).

Data from this indicator type have been used to detect and track population declines as they relate to ecosystem change (Veit et al. 1996, Veit et al. 1997, USFWS 2009, Piatt et al. 2011). Although establishing habitat use is relatively straightforward, understanding the ecological mechanisms driving those patterns may be more difficult to accomplish, as it requires understanding the variance and persistence of underlying marine processes over time (Weimerskirch 2007, Nur et al. 2011, Suryan et al. 2012). In the absence of long-term data sets, data from this indicator can be combined with other ecosystem indicators such as reproductive output and diet to make strong inferences and predictions about ecosystem change (Piatt et al. 2007, Field et al. 2010, Cury et al. 2011).

Clear indicator response to management actions, reference points, and targets is possible in systems where actions include introduction, re-introduction, or exclusion of birds from nesting or foraging habitat or significant changes in fisheries practices where bycatch is management concern (Roby et al. 2002, Suryan et al. 2004, Lyons et al. 2005). In other cases, isolating the response to specific management actions or other pressures can be difficult because many factors affect habitat use.

DATA CONSIDERATIONS.

Quantitative, operationally-straightforward methods to examine habitat use in space and time are well-established for direct observation from ships (Tasker et al. 1984, Spear et al. 1992), land (Zamon 2003, Zamon et al. 2007), and air (Briggs et al. 1985a, Mason et al. 2007). Telemetry methods are more complex but also well-established (Burger and Shaffer 2008, Hart and Hyrenbach 2009). While telemetry can provide geographical coverage of an entire ecosystem (Adams et al. 2012), there are substantial spatial and temporal data gaps for direct observations of seabirds at sea (see “Data gaps” section). California is relatively well-

sampled because long-term observations are maintained in both southern (CalCOFI/CCE-LTER sites: www.calcofi.org, cce.lternet.edu) and central California (www.sanctuarysimon.org). Northern California and southern Oregon coasts have no regular sampling programs, and the only annual ocean ecosystem sampling program for northern Oregon and Washington is presently in immediate jeopardy of ending (<http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm>). For the central and northern domains of the CCLME, winter data on seabird distributions and abundance at sea are rare.

Although data gaps exist in spatial and temporal coverage of the CCLME, there is a well-developed world-wide literature on understanding spatial and temporal variation in seabird habitat use at sea, including the seminal paper by Hunt and Schneider (1987) and other more recent syntheses (Fauchald 2009, Gonzalez-Solis and Shaffer 2009), as well as an extensive literature for those parts of the CCLME where data exist (Ainley et al. 2005, Ainley et al. 2009, Sydeman et al. 2009, Ainley and Hyrenbach 2010, Adams et al. 2012, Suryan et al. 2012, Zamon et al. 2013).

OTHER CONSIDERATIONS.

The use of direct observations, counting, and telemetry to understand how animals are using habitat is something that is intuitively communicated to and understood by both the public and managers. Maps of habitat use are one of the most intuitive tools for communication, and are commonly used in guiding management actions, policy, regulatory processes, and educational or outreach materials. Students can be utilized for some types of data collection. Pairing bird observations with at-sea physical or biological oceanographic surveys and other platforms of opportunity can make this type of data very cost-effective and can provide significant value-added information for ecosystem management. The National Seabird Program, for example, has recently put seed funding into capital equipment purchases for the Northwest Fisheries Science Center so observers can be deployed on ships-of-opportunity, and the Oregon Wave Energy Trust has provided funding to pay trained observers for two surveys. Additional cost-savings are possible by increasing the use of NOAA's Small Boat Program (< 65 ft.) to conduct nearshore surveys, a cost-effective strategy employed by other federal and state agencies in California, Oregon, and Washington (Strong 2009, Pearson et al. 2011). Quantitative use of these data to generate leading indicators of change is not very common, although there are intriguing possibilities suggested by some investigators for birds which migrate north to the CCLME from the southern hemisphere (Lyver et al. 1999, Hyrenbach and Veit 2003). Indicator data are already being used to predict future habitat opportunity, habitat degradation, or potential conflict with human uses (Burger and Shaffer 2008, Nur et al. 2011, Suryan et al. 2012). All of the data types for this indicator are used for and compatible with regional, national, and international work, especially work to identify marine habitats of international conservation concern (e.g. <http://web4.audubon.org/bird/iba/>, see also (Burger and Shaffer 2008, Hart and Hyrenbach 2009, Croxall et al. 2012).

DATA GAPS.

Temporal and spatial coverage is generally of higher resolution in the southern and central domains of the CCLME due to maintenance of the CalCOFI and NOAA Fisheries rockfish surveys over several decades, and due to the location of several National Marine Sanctuaries in California actively involved in at-sea research. Some historical information for the Olympic Coast National Marine Sanctuary exists from ship-based work (http://olympiccoast.noaa.gov/science/surveyscruises/2011/seabird_density.html), and a new small boat ocean survey began in 2011

(<http://olympiccoast.noaa.gov/science/surveyscruises/2011/marinebirds.html>). There are no National Marine Sanctuaries in Oregon.

Annual Ocean Ecosystem Surveys by NOAA Fisheries NWFSC on the Oregon and Washington coasts began in 1998. In addition to collecting data characterizing physical ocean conditions, chlorophyll-*a* distribution, zooplankton communities, juvenile salmon distributions, and epipelagic fish communities, these also include shipboard surveys of seabird distribution and abundance after 2003 (<http://www.nwfsc.noaa.gov/research/divisions/fed/oceanecology.cfm>). The Ocean Ecosystem Surveys filled a data gap for habitat-at-sea information in the northern CCLME domain; however, this entire program is in immediate jeopardy of losing funding for ocean surveys.

Similarly, the use of telemetry to examine bird use of habitat at sea is more frequently used in California than in either Oregon or Washington. Therefore, less is understood about seabird habitat use in the northern domain of the CCLME, although there are notable exceptions such as Hamel et al. (2008) and Adams et al. (2012).

Information on fall and winter habitat use at sea from shipboard or aerial surveys is very rare due to two primary limiting factors. First, there are simply fewer research surveys take place during fall and winter than during spring and summer. More importantly, however, there is no consistent funding source to support placing trained observers on the survey platforms that do go to sea in these seasons. Some winter surveys have been funded as part of collecting baseline ecological data for ocean energy development (Zamon, unpublished data). With a modest amount of support for trained observers, the use of ships-of-opportunity could be better developed for all domains of the CCLME.

SEABIRD POPULATION SIZE AND CONDITION – ANNUAL REPRODUCTIVE PERFORMANCE

- (2) ***Annual reproductive performance.*** For purposes of this evaluation, the metric “annual reproductive performance” includes quantifying metrics such as the number of breeding pairs (direct observation, plot counts, nest counts, or aerial photographs), timing of egg-laying, egg production, timing of hatching, hatching success, chick growth, timing of fledging, fledging success, fledgling mass, and juvenile-to-adult ratios.

THEORETICAL CONSIDERATIONS.

The use of annual reproductive performance to track population trends and responses in seabirds is well-accepted and a required part of seabird population ecology and conservation, as it allows one to measure responses to both ecosystem change and management actions (Cairns 1987, Furness and Camphuysen 1997, Nur and Sydeman 1999, Caswell 2006, Piatt et al. 2007, Gaston et al. 2009, Field et al. 2010, Cury et al. 2011). Counts and identification of breeding pairs from colonies is necessary to include because state and federal management agencies require information on population sizes for management and conservation actions. Information on annual reproductive performance has been used to set and monitor defined reference points and targets for population recovery, as well as document range expansions or contractions of breeding birds (USFWS 2009, Wolf et al. 2009, Cury et al. 2011). Attribution of population responses to specific ecosystem changes or management actions requires the synthesis of several variables to make strong inferences regarding mechanisms driving population change (Frederiksen et al. 2007).

Tracking abundance trends of multiple coexisting species on breeding colonies is accepted standard operating procedure for quantifying seabird population size (Ainley et al. 1994, Walsh et al. 1995). Having quantitative population estimates is essential for agency agreement on managing species protected by the Migratory Bird Treaty Act (1918) and the Endangered Species Act (1973) (Warzybok and Bradley 2010). Because seabirds are long-lived species with low variation in reproductive rates, it can be difficult to attribute population responses to specific causes such as ecosystem-wide change in ocean climate, regional changes in the forage base, or local effects on a particular colony (Manuwal et al. 2001, Thibault et al. 2010). Land-based management actions such as predator removal, invasive species control, and limiting human disturbance are often easier to link to population responses than marine-based management actions (USFWS 2008, Dunlevy et al. 2011, Towns et al. 2011). However, reference points and targets for populations are often set in terms of population size thresholds for protected species such as marbled murrelets (*Brachyramphus marmoratus*) or short-tailed albatross (*Phoebastria albatrus*), so this metric is important to practical stewardship in management agencies (USFWS 1997, 2006, 2008).

It is important to note, however, that CCLME habitat is important to non-breeding individuals and migratory populations as well. In those cases, indicator data of this type would necessarily come from research and monitoring external to the CCLME ecosystem.

DATA CONSIDERATIONS.

Data of this type are quantitative and operationally simple to measure (Sydeman et al. 2001). Historical data records are available from at least one source in all three domains of the CCLME (Sydeman et al. 2001, Saenz et al. 2006, Thayer and Sydeman 2007, Millus and Stapp 2008, Gaston et al. 2009). Sites with the most complete and consistent temporal coverage are in southern and central CCLME, whereas coverage in the northern domain is typically too sparse for time series analysis except in one or two cases (Lee et al. 2007, Sydeman et al. 2009).

Quantitative methods for surveying seabird colonies are well-established (Ainley et al. 1994, Walsh et al. 1995), and historical data do exist for some well-studied species in the CCLME dating back to the 1960s (Anderson and Gress 1983, Ainley et al. 1994). Very few species are monitored with broad geographic coverage throughout the CCLME (although the common murre *Uria aalge* is an exception to this, (Manuwal et al. 2001)). The Farallon Islands in the central domain of the CCLME has the most complete multispecies, time series data set (Warzybok and Bradley 2010). Spatial and temporal variation in breeding numbers is influenced by a number of factors which can make it difficult to separate cause and effect. Local predator disturbance at colonies is becoming an increasingly important confounding factor when attempting to attribute population responses to terrestrial vs. marine causation (e.g. Hipfner et al. (2012)). There is often a low signal-to-noise ratio inherent in seabird population counts due to their longevity and low reproductive rates (Ainley and Boekelheide 1990, Ainley et al. 1994).

Recognition of the importance of annual reproductive performance data to ecosystem management is growing. Investigators are establishing new monitoring programs or resurrecting discontinued programs in key areas to fill data gaps (see “Data Gaps”, this section).

OTHER CONSIDERATIONS.

Population counts are readily understood by the public and by managers because this is the most commonly used metric of population size for all organisms. In areas where there is conflict caused by seabird

predation on ESA-listed species (e.g. Pacific salmon in estuaries and coastal areas), population size is of both public and management concern (e.g. Good et al. (2007), Anderson et al. (2004)). Counting birds on colonies is generally accepted as a reliable and meaningful method to track seabird populations (Ainley et al. 1994, Walsh et al. 1995). Although it can be expensive to maintain long-term colony monitoring for areas where access to remote sites is required, cost-sharing by multiple agencies and organizations can make such programs affordable. Pairing this work with a larger research effort is also a way to keep data collection cost-effective (Mallory et al. 2010). Population size is typically used for retrospective analyses (e.g. Piatt et al. (2007). However, present population size and past variation in population size can be used to project extinction probabilities into the future, and in some cases these are being explored as ways to manage ESA-listed bird species such as the marbled murrelet and short-tailed albatross (USFWS 2008, 2009). Seabird colony counts are found elsewhere in the region, nation, and world. For reviews of global information, see Anker-Nilssen et al. (1996), Walsh et al. (1995), and Hatch (2003).

The concept of successfully replacing adults with offspring to maintain population viability is an intuitive one that is readily communicated to and understood by the public and resource managers. Popular culture maintains an interest in seabirds through production of nature shows for television and film. Some recent work is beginning to explore predictive applications for annual reproductive performance (Kitaysky et al. 2010), but in general these data provide retrospective and real time measures of population condition, not predictive measures. This data type is collected regionally, nationally, and internationally, and has been used to make global inferences and recommendations for fisheries practices (Cury et al. 2011).

DATA GAPS.

Consistently-maintained time series with durations greater than 10 years are missing from the northern domain of the CCLME. New information is becoming available on the Washington coast for a few locations (Destruction Island, Tatoosh Island, and Protection Island), via collaborations among Washington Department of Fish and Wildlife, the University of Puget Sound, the University of Washington, and NOAA Fisheries NWFSC (S. Pearson, P. Hodum, and T. Good, pers. comm; see also <http://wdfw.wa.gov/conservation/research/projects/seabird/>). Coverage of annual reproductive performance on the Oregon coast is particularly lacking, in part due to the logistical difficulty of accessing colonies and in part due to lack of historical programs. Robert Suryan (Oregon State University) is establishing a program at Yaquina Head, OR. Unfortunately, one monitoring program which had been maintaining historical data sets on Leach's storm-petrel (*Oceanodroma leucorhoa*) at Saddle Rock, OR, recently ended because that storm-petrel population was wiped out by raccoon and river otter predation on the colony (Janet Hodder, University of Oregon, pers. comm.).

Colony counts may or may not be made on an annual basis, depending on resources available to the agencies responsible for conducting surveys (e.g. Naughton et al. (2007)). Colony sizes can be quite dynamic, especially in recent years when predator disturbance has become an issue (Hipfner et al. 2012). In general, California, Oregon, and Washington do maintain inventories of seabird colony locations and sizes through federal and state wildlife programs.

With the exception of the ESA-listed marbled murrelet (*Brachyramphus marmoratus*), variation in the reproductive performance of less common seabird species, species that do not nest in dense colonies, and species that do not breed in the CCLME, is not as well-documented. Many species use the CCLME but do not breed in the CCLME, so measures of reproductive performance need to come from other ecosystems. Cross-ecosystem integration for conservation purposes is recognized as important but is not commonly practiced

(Nevins et al. 2009). For example, the most common bird in the CCLME during summertime, the sooty shearwater (*Puffinus griseus*) breeds in New Zealand and Chile; albatross species of conservation concern (Diomedidae) breed on tropical or subtropical offshore Pacific islands; and pelagic seabirds such as northern fulmars (*Fulmarus glacialis*) and black-legged kittiwakes (*Rissa tridactyla*) breed in Alaska.

SEABIRD POPULATION CONDITION – COUNTS AND IDENTIFICATION OF MORTALITY

- (3) ***Mortality rates and agents.*** For purposes of this evaluation, the metric “mortality rates and agents” includes metrics such as number and species of mortalities reported from various sources including but not limited to mass strandings, beach-cast birds, bycatch in fisheries, harmful algal blooms, disease/pathogens/parasites, predation, collisions, and pollution/spills. It is also intended to include necropsy data where cause of death can be established.

THEORETICAL CONSIDERATIONS.

The ability to quantify mortality effects and mortality sources is a key element of population ecology. There is good support for examining mortality in seabirds as a way to understand what mortality factors are affecting bird populations (Camphuysen and Heubeck 2001, Roletto et al. 2003, Moore et al. 2009, Materna et al. 2011, Phillips et al. 2011). Bycatch impacts from fisheries is of management concern (Fitzgerald et al. 2008). Mass strandings, beached birds, and oil spill mortality are of concern to scientists, management, and the public. Attributing cause to these mortality events may be straightforward in some cases (Phillips et al. 2011) but not in others (Parrish et al. 2007). Fisheries bycatch is one mortality agent for which a direct response to management action is measurable (Melvin et al. 2001, Fitzgerald et al. 2008). Mortality measures are actively used as management reference points and targets for populations of ESA-listed species (USFWS 1997, 2006, 2008) and for bycatch thresholds which trigger fisheries closures (USFWS 2008).

DATA CONSIDERATIONS.

Standard protocols for monitoring, reporting, and quantifying mortality are available and commonly used (Roletto et al. 2003, Hamel et al. 2009, Moore et al. 2009, Phillips et al. 2010, Phillips et al. 2011). Historical data are with relatively broad spatial coverage and good time series are available for beached bird surveys and inferred gill net mortality in the CCLME (Parrish et al. 2007, Moore et al. 2009), but information from direct observations of bycatch in West Coast fisheries is only now starting to be investigated (Jannot et al. 2011). There is a coordinated, multi-agency network in place to collect specimens from oil spills, but data are often subject to severe access restrictions because they are considered evidence for legal proceedings. Compiling recent or historical data on oil spill mortality can therefore be logistically complicated. There is no existing coordinated multi-agency effort to integrate coverage of episodic mortality events which are not caused by oil spills, but it is recommended that one be established to assist with documenting these types of mortality events, especially given ocean climate change may impact the frequency and intensity of harmful algal blooms (Phillips et al. 2011).

Understanding of spatial and temporal variation in seabird mortality is not well-developed, although the factors affecting mortality are theoretically understood (Camphuysen and Heubeck 2001, Parrish et al. 2007). The episodic nature of mortality events that humans can observe is almost always confined to events on or near shore, although there are rare occasions when mortality at sea is documented (Baduini et al. 2001). High variability in the probability of detecting mortality also makes it difficult to track trends in overall

mortality over time. Partitioning mortality from one source (e.g., derelict fishing gear) relative to other sources (e.g., bycatch from active fishing) can be difficult due to a lack of comparable data from multiple mortality sources (Good et al. 2009). Except for certain cases where population sizes of ESA-listed species are known, it is most often unknown what portion of overall mortality each specific type of seabird mortality represents.

OTHER CONSIDERATIONS

Death and causes of death in wildlife are concepts which are commonly understood by citizens and managers. Mortality events are often highly visible to the public and almost always result in public inquiries as to the cause of such mortality events. In some cases, the public is the first to report an event that triggers agency responses (Phillips et al. 2011). Images of dead birds entangled in fishing gear, oiled by pollution, or emaciated due to starvation are powerful tools for communicating messages about ecosystem risk and health to the public and to managers. Recovery of specimens for necropsy can often be cost-effective, making use of volunteers and staff from multiple agencies in a response situation. Beached bird surveys are volunteer-driven and provide good examples of citizen-science in action which are used not only in the CCLME (for example, www.sanctuarysimon.org/monterey/sections/beachCombers/index.php, (Parrish et al. 2007)), but in other regions and countries as well (Powelsland and Imber 1988, Camphuysen and Heubeck 2001, Wiese and Ryan 2003, Zydels et al. 2006).

DATA GAPS.

Beached bird programs have good coverage over much of the west coast where public beaches are available. Seabird bycatch in West Coast fisheries is not as quantitatively or broadly monitored as it is in Alaska, but that is starting to change as fishery observer data sets become available to seabird biologists due to concern about recent ESA-listed species interactions with some fishery sectors. For example, a new, collaborative program to quantify bycatch from commercial fisheries in the CCLME has begun with scientists from Washington Sea Grant (E. Melvin and T. Guy, <http://wsg.washington.edu/mas/resources/seabird.html>), NOAA Fisheries NWFS West Coast groundfish observer program (J. Majewski, <http://www.nwfsc.noaa.gov/research/divisions/fram/observer/index.cfm>), and NOAA Fisheries Alaska Regional Office (K. Rivera and S. Fitzgerald, <https://www.fakr.noaa.gov/protectedresources/seabirds.htm>). Specimen recovery from bycatch for necropsy analysis is not yet established; we recommend necropsy analysis be supported.

Growing concern over the potentially increasing frequency, intensity, and duration of harmful algal blooms, and their impacts on seabirds, points to a need for a rapid, interdisciplinary response to understanding these ecosystem events as mortality sources for seabirds as well as other living marine resources (Jessup et al. 2009, Phillips et al. 2011).

The biggest data gap is in understanding natural, non-anthropogenic mortality at sea. This gap may be very difficult to fill because observations of natural mortality at sea are very rare. The best that can be done at this time is to take full advantage of opportunities to study at-sea mortality events whenever possible (e.g. Baduini et al. (2001)).

FINAL SUITE OF INDICATORS

Selection of a final, complete suite of indicators was discussed, and final indicator choice was based on the following criteria:

- rank score of 17 possible,
- the desire to include representative indicators for population size and condition for both breeding and non-breeding/migrant birds,
- the need to avoid redundant information, and
- the need to include complementary data types.

The Final Four seabird indicators we selected, with their cumulative score out of 17 possible, were:

- (1) Indicator: habitat use at sea (Attribute: population size and condition, 15/17)
- (2) Indicator: annual reproductive performance (Attribute: population size and condition, 14.5/17)
- (3) Indicator: counts and identification of mortality and mortality agents (Attribute: population condition, 14.5/17)
- (4) Indicator: diet composition (Attribute: population condition, 13.5/17)

The Top Three indicators were included for reasons discussed in the previous section.

Because we are explicitly interested in ecosystem-based management, we also decided it was critical to seabird diet as an indicator. Diet information is necessary to determining what food resources are being used by seabirds. Without it, one cannot link lower trophic level production in the ecosystem to birds, and one cannot make inferences or predict how ecosystem or fisheries management changes at lower trophic levels will affect seabirds.

Specific information supporting inclusion of diet as an indicator is discussed below.

SEABIRD POPULATION CONDITION – DIET COMPOSITION

- (4) ***Diet composition.*** For purposes of this evaluation, the metric “*diet composition*” includes methods such as traditional gut content and prey identification analysis, scat analysis, observations of bill loads, direct observation of predation events, stable isotope analysis, fatty acid analysis, and molecular analysis of prey remains. Diet composition also includes not only prey items fed to chicks (the most commonly collected diet information), but also prey taken by non-breeding birds and adults for self-feeding.

THEORETICAL CONSIDERATIONS.

Diet information is required by managing agencies to determine what prey species are supporting seabird populations in ecosystem-based management (Schrimpf et al. 2012). The use of diet data to track changes in prey use and prey resources as well as foraging and breeding success is widely accepted and has been used in the CCLME (Cairns 1987, Barrett et al. 2007, Piatt et al. 2007, Sydeman et al. 2009). The influence of fisheries discards on diet composition needs to be considered for some species, as has been seen in other systems (Navarro et al. 2009, Bugoni et al. 2010, Vaske 2011). Inferences from stable isotopes and fatty acids are more complicated to interpret because factors other than prey type can influence chemical composition (Iverson et al. 2007, Sears et al. 2009, Williams and Buck 2010). The most powerful approaches

use two or more tools to examine diet composition (Sydeman et al. 1997, Karnovsky et al. 2008). In addition to informing management about seabirds, diet information can evaluate the direct effects of birds on prey species of conservation concern such as Pacific salmon (Roby et al. 2003) and can track ecosystem or prey community changes in the marine environment (Thayer et al. 2008). Diet information has also been used to evaluate the effectiveness of specific fisheries management actions (e.g. reducing avian predation on Pacific salmon), the potential effects of ocean energy development on prey species consumed by seabirds, and the ability to meet management targets for bird population sizes. However, partitioning the response component between management action and natural variation can be difficult (Pichegru et al. 2010, Perrow et al. 2011). In some cases, stable isotope and fatty acid sampling have been used to make inferences about resources supporting protected species and non-breeding species when it is not possible to sample diet directly (Kakela et al. 2010, Ronconi et al. 2010).

DATA CONSIDERATIONS.

Diet data are quantitative and well-accepted by seabird ecologists as indicators of what species in an ecosystem are necessary to support seabird populations (see comprehensive methodological review by Barrett et al. (2007)). Historical data from the 1970s, 1980s, and 1990s exist in locations within the CCLME (Gaston et al. 2009, Sydeman et al. 2009). Examination of museum specimens with stable isotope methods is possible (Newsome et al. 2010). Fatty acid data, however, were not commonly archived in historical data sets, as the frozen storage necessary to preserve specimens has only recently become available. Geographical coverage of diet in any form is limited to a handful of sites sparsely distributed in the three domains of the CCLME (Channel Islands, CA; Farallon Islands, CA; San Francisco Bay, CA; Yaquina Head, OR; East Sand Island, OR; Destruction and Tatoosh Islands, WA – see Warzybok and Bradley (2011), Suryan et al. (2011), and Roby et al. (2003) for a few examples). Relatively continuous time series of diets for any species are rare; the most complete data set is from the Farallon Islands in the central CCLME domain, and this information is often used to make inferences for the entire CCLME. These inferences may not be appropriate for the northern and southern biogeographic domains of the CCLME because of the different physical and biological processes driving prey community dynamics in those locations.

OTHER CONSIDERATIONS.

It is well-understood by both the public and resource managers that an ecosystem must sustain the right kind and right amount of prey species to maintain healthy seabird populations. Diet is therefore perceived as being a reliable and meaningful indicator of what ecosystem resources are necessary to support seabird populations. There has been a great deal of recent public and legal attention given to the ecological importance of coastal pelagic species (forage fishes) in supporting many components of the CCLME (Enticknap et al. 2011). Field collections and processing of diet data can be labor-intensive. However, multi-agency partnerships (Suryan et al. 2011, Warzybok and Bradley 2011) and opportunistic sampling (Lance and Pearson 2012) can significantly increase cost-effectiveness. Although not typically used to forecast population trends in birds, some studies have shown that diet quality can predict subsequent reproductive success or survival (Sorensen et al. 2009, Kitaysky et al. 2010). Diet information from seabirds is collected worldwide, and comparisons can be made among sites when similar methodology is used (Barrett et al. 2007). Examples of recent global and regional reviews, including the CCLME, can be found in Cury et al. (2011), Gaston et al. (2009), and Sydeman et al. (2009).

DATA GAPS.

Almost all diet studies report what prey types breeding birds are feeding to chicks. Diets of adult birds, non-breeding birds, and migrants have seldom been examined in the CCLME (for an exception, see Varoujean and Matthews (1983)), and no time series for these diet types are available to our knowledge. Virtually nothing is known of winter diets for non-breeding birds in the CCLME. Because ocean climate shifts have significant effects on the species composition of fish and zooplankton, historical diets do not necessarily provide an accurate representation of present-day diet composition.

INDICATORS NOT INCLUDED IN THE FINAL SUITE

Two relatively high-ranking indicators had tied scores with indicators in the final suite of selected indicators, but were not selected as part of that final suite of five indicators (Counts and identification of birds at sea, score 13.5/17; and contaminant loads, score 13/17). Because determining habitat use at sea requires survey data from counts at sea, we considered it appropriate to drop counts and identification of birds at sea as a separate indicator from our final list due to the redundancy of information in these related indicators. Similarly, because it would be possible to include screening for tissue contaminant load in other sampling, and because historical records of contaminant loads are not common, we considered it appropriate to drop tissue contaminant load as a separate indicator. Instead we urge investigators to sample contaminants whenever possible opportunities for tissue samples arise (e.g. when salvaging dead specimens, tagging live specimens, or handling birds on the colony).

It was noted that multivariate seabird indices (score 11.5/17) could be derived from data types in the final list we selected. Therefore, this indicator type would be implicitly included seabird indicator data.

The other four candidate indicators ranked lower in cumulative scores (<11.5) and were therefore not included in the final list. The reasons for this typically included difficulty in detecting or attributing trends in these indicators to specific CCLME changes or management actions, a lack of historical information with good temporal or geographic coverage, and fewer papers available in peer-reviewed literature applying those indicators to ecosystem questions. We did not think that any of these lower-ranking indicators would miss a critical or essential component of ecosystem information at this time.

Table SB1. Summary of seabird indicator evaluations. The numerical value that appears under each of the considerations represents the score from evaluation criteria supported by peer-reviewed literature. Initials of the individual evaluating each indicator are provided.

CONSIDERATIONS					
Attribute	Indicator	Primary (5)	Data (7)	Other (6)	Summary comments
Population size & condition	(1) Habitat use at sea	4	7	4	Essential indicator, demonstrated literature support for utility. Necessary to obtain information on non-breeding residents and migratory species. Primary methods include ship, land, or aircraft-based surveys, but individually-based marking and telemetry also provide complementary data. Oregon, Washington less well-studied than California. Winter conditions poorly understood in most locations. (JEZ)
Population condition	(2) Annual reproductive performance	4.5	6.5	3.5	Essential indicator with strong literature support for data utility. Long-term data sets exist in all domains of California Current, but need to fill gaps in Oregon and some areas of Washington. Applies to breeding residents; data for not non-breeding residents or migratory species must come from studies external to the California Current. (WJS)

CONSIDERATIONS					
Attribute	Indicator	Primary (5)	Data (7)	Other (6)	Summary comments
Population condition	(3) Counts, identification of mortality, morality agents	4	6	4.5	Required to assess population risk and suggest management actions for population recovery. Includes predators, disease, pathogens, parasites, contaminants/pollution, starvation, collisions, senescence. Mortality often highly visible to public. Long-term data sets exist for certain types of mortality: beach-cast birds, fisheries bycatch for all geographic domains. (TPG)
Population condition	(4) Diet	4	5.5	4	Necessary to link seabirds to food web components supporting seabird populations. Strong literature support for data utility, but most data sets examine chick diet, not adult or non-breeder diet. Geographic gaps in diet information for Oregon, Washington. (JEZ)
Population size	(5) Counts, identification of birds at sea	4.5	5.5	3.5	Essential indicator, demonstrated literature support for utility. Necessary to obtain information on non-breeding residents and migratory species. Also provides information on habitat use at sea. (JEZ)

CONSIDERATIONS					
Attribute	Indicator	Primary (5)	Data (7)	Other (6)	Summary comments
Population condition	(6) Contaminant loads	4	5.5	3.5	Useful to understand health of individuals, populations, and food web. However, not often collected, historical sampling across many species is missing, requires additional diet information to interpret. (TPG)
Population size	(7) Counts, identification of birds at colonies (breeding populations only)	4	5.5	3.5	Essential indicator, demonstrated literature support for utility. Can include on-colony counts as well as aerial surveys. Historical data from most areas available. However, considered redundant with (2) because that data type includes counts of breeding pairs as a component of annual reproductive performance. (TPG)
Population condition	(8) Multivariate seabird index	4	5	2.5	Requires other indicator data to be collected for meta-analysis. Not widely applied, but successful when applied. Non-intuitive for public application. (WJS)

CONSIDERATIONS					
Attribute	Indicator	Primary (5)	Data (7)	Other (6)	Summary comments
Population size	(9) Counts, identification of shorebird species in coastal habitats	3.5	6	2.5	Responses in shorebirds may be primarily due to local land-use practices rather than changes in the California Current large marine ecosystem <i>per se</i> . However, ocean climate change could affect food resources and available habitat for shorebirds. (TPG)
Population condition	(10) Survival rates, other demographic variables	3.5	4	3.5	Trends and responses in this indicator alone difficult to attribute to specific ecosystem change or management without context of data from other indicators. (WJS)
Population size & condition	(11) Metapopulation structure/dynamics	3	4	3.5	Includes both mark-recapture techniques and newer molecular techniques to examine population size, mixing, and migration. Few species have comprehensive information on metapopulation structure in California Current, but can be important for conservation applications. (JEZ)

CONSIDERATIONS					
Attribute	Indicator	Primary (5)	Data (7)	Other (6)	Summary comments
Population condition	(12) Stress hormones	3	1	2	Relatively new in application to seabirds. Powerful for looking at individual responses to starvation or disturbance, but has not been scaled up to examine population level responses. Stress responses may occur on too short of a time scale to be useful as ecosystem indicator. (WJS)

Table SB2. Potential data sets available for contemporary seabird indicator data.

	Program title	Institution responsible for contemporary data collection	Indicator data type	Area of coverage	Data contact
1	California Current Cetacean and Ecosystem Assessment Surveys	NOAA - Southwest Fisheries Science Center – Protected Resources Division	Habitat use at sea	California, Oregon, Washington	Lisa Ballance – lisa.ballance@noaa.gov
2	California Cooperative Oceanic Fisheries Investigations (CalCOFI)	Farallon Institute & PRBO Conservation Science	Habitat use at sea	Southern California	William Sydeman – wsydeman@faralloninstitute.rc
3	Mediterranean Coast Network	Channel Islands National Park	Reproductive performance Breeding colony counts Diet	Channel Islands, California	Russell Galipeau – 1-805-658-5700
4	Applied California Current Ecosystem Studies (ACCESS)	PRBO Conservation Science	Habitat use at sea	Cordell Bank, Gulf of the Farallones, Monterey Bay National Marine Sanctuaries	Jaime Jahncke – jjahncke@prbo.org
5	PRBO Seabird Monitoring on the Farallon Islands	PRBO Conservation Science	Reproductive performance Breeding colony	Farallon Islands, California	Jaime Jahncke – jjahncke@prbo.org

Program title		Institution responsible for contemporary data collection	Indicator data type	Area of coverage	Data contact
			counts		
			Diet		
6	NOAA Fisheries Rockfish Surveys	Farallon Institute & PRBO Conservation Science	Habitat use at sea	Central California	William Sydeman – wsydeman@faralloninstitute.org
7	At Sea Marbled Murrelet Population Monitoring	Crescent Coastal Research	Habitat use at sea	Northern California to Northern Oregon	Craig Strong – cstrong.ccr@charter.net
8	Ocean Salmon Ecosystem Survey	NOAA –Southwest Fisheries Science Center – Fisheries Ecology Division	Habitat use at sea	Newport, OR to San Francisco, CA	Sean Hayes – sean.hayes@noaa.gov
9	Beach COMBERS	Moss Landing Marine Laboratories	Mortality – beaches	Central California	Hannah Nevins – hnevins@mlml.calstate.edu
10	Seabird Bycatch	NOAA – Northwest Fisheries Science Center – Fishery Resource Analysis and Monitoring Division	Mortality –bycatch in commercial fisheries	California, Oregon, Washington	Janell Majewski – janell.majewski@noaa.gov
11	Pacific Continental Shelf Environmental	USGS – Western Ecological Research	Habitat use at sea	Fort Bragg, CA to Grays Harbor,	Josh Adams –

	Program title	Institution responsible for contemporary data collection	Indicator data type	Area of coverage	Data contact
	Assessment (PaCSEA)	Center		WA	josh_adams@usgs.gov
12	Catalog of Oregon Seabird Colonies	USFWS – Newport Office	Breeding colony counts	Oregon	Roy Lowe – roy_lowe@fws.gov
13	Yaquina Head Seabird Study	Oregon State University	Habitat use at sea Reproductive performance Diet	Central Oregon	Robert Suryan – rob.suryan@oregonstate.edu
14	Ocean Salmon Ecosystem Survey	NOAA – Northwest Fisheries Science Center – Fish Ecology Division	Habitat use at sea Diet	Newport, OR to Cape Flattery, WA	Jeannette Zamon – jen.zamon@noaa.gov
15	Columbia River Avian Predation Project	Oregon State University	Reproductive performance Diet Breeding colony counts	East Sand Island, OR	Daniel Roby – daniel.robby@oregonstate.edu
16	Marine Bird and Mammal Surveys	NOAA – Northwest Fisheries Science Center – Fish Ecology Division	Habitat use at sea	North Head, WA	Jeannette Zamon – jen.zamon@noaa.gov
17	At Sea Marbled Murrelet	Washington	Habitat use at sea	Washington	Scott Pearson –

	Program title	Institution responsible for contemporary data collection	Indicator data type	Area of coverage	Data contact
	Population Monitoring	Department of Fish and Wildlife	Reproductive performance Diet		scott.pearson@dfw.wa.gov
18	Coastal Observation and Seabird Survey Team	University of Washington	Mortality – beaches	Washington, Oregon, California	Julia Parrish – jparrish@u.washington.edu
19	Pelagic Seabird Surveys	NOAA – Olympic Coast National Marine Sanctuary	Habitat use at sea	Grays Harbor, WA to Cape Flattery, WA	Liam Antrim – liam.antrim@noaa.gov

Table SB3. Indicators used to examine Status and Trends data.

Attribute	Indicator	Definition and source of data	Time series	Sampling frequency
Population size & condition	Habitat use at sea – northern domain	Northwest Fisheries Science Center Ocean Salmon Ecosystem surveys, from Newport, OR (44°40'N) to the Washington-British Columbia border (48°13'N). Strip-transect surveys of seabird distribution and abundance from NOAA-chartered research vessels.	2003 – 2012	May, Jun surveys annually
	Habitat use at sea – southern domain	California Cooperative Oceanic Fisheries Investigations surveys, transects from San Diego, CA (30°N) to Point Conception, CA (35°N).	1987 – present	Jan/Feb, Apr, Jul surveys annually

STATUS AND TRENDS

MAJOR FINDINGS

The CCLME seabird community consists of over 75 species of seabirds, the composition of which changes seasonally and includes breeding residents, nonbreeding residents that reside in the CCLME habitat for several months during their nonbreeding season, and migratory species which transit relatively rapidly through CCLME habitat during spring and fall migrations (e.g. Ainley and Hyrenbach (2010), Ford et al. (2004)). To measure status and trends in seabird populations, it is necessary to have time series which measure seabird indicator data for the last five years (2007-2011) as well as for earlier years from which a long-term mean can be calculated. Measures such as bird density (birds per km²) should track population trends over time. Measures such as diet would track whether or not the food resources supporting seabird populations are changing over time.

Unlike fish or mammal data sets required by NOAA Fisheries for annual stock assessments, most seabird indicator data sets are collected by many different institutions or individuals. Seabird programs frequently depend on funding from a variety of sources to support research or maintain time series because few data sets have long-term funding necessary to maintain relatively unbroken time series of seabird indicators. These circumstances make it challenging to maintain, integrate, and synthesize data sets required to track ecosystem trends and responses (e.g. Ford et al. 2004).

Literature searches and communications with professional contacts for the 2012 IEA process revealed that at least 19 sources of historical seabird indicator data, with accompanying contemporary data, are potentially available from all three biogeographic domains within the CCLME (i.e. southern, central, and northern; Table SB2). Reviews of status and trends for time series of habitat use at sea, annual reproductive performance, and diet exist for pre-2010 data sets, with at least one indicator reviewed in each CCLME domain (Hyrenbach and Veit 2003, Gaston et al. 2009, Sydeman et al. 2009, Ainley and Hyrenbach 2010, Cury et al. 2011). However, recent data necessary for the 2012 IEA process (2007-2011) were often not publicly or readily available in the format required for data processing to examine trends for the last five years.

Given the situation with contemporary data for seabird indicator variables, it was beyond the scope of 2012 IEA resources to secure access to, examine, and synthesize all potential indicator data sets. We recommend that support for various institutions to contribute to synthesis of as many indicator data sets as possible be made available in the future.

We were, however, able to examine sample data sets for “At sea habitat use” which were immediately available for the IEA process through two of our seabird subgroup members (JEZ – Ocean Salmon Ecology data, WJS – CalCOFI data). These data sources are summarized briefly in Table SB3.

SUMMARY OF STATUS AND TRENDS FOR SAMPLE INDICATOR TIME SERIES

SAMPLE INDICATOR TIME SERIES

Data from two long term studies of seabird habitat use at sea were available for inclusion in the 2012 IEA. These data are being collected as part of ecosystem studies in the northern CCLME (Ocean Ecosystem Surveys - <http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm>); and southern CCMLE (California Cooperative Oceanic Fisheries Investigations (CalCOFI) - <http://www.calcofi.org/>). These data provide a first look at the most recent abundance trends for representative seabird species at sea which have been examined in peer-reviewed literature.

Data collected during both studies were derived from counts of all birds seen within a 300-m wide strip while the research vessel was underway (for detailed methodology, see Tasker et al. (1984) and Heinemann (1981)); therefore, data include breeding residents, nonbreeding residents, and migratory populations. These counts were converted to mean densities of birds per km⁻² for each annual cruise. Data were log(x+1) transformed to normalize the data distribution and assist in visualization of short- and long-term trends.

SEABIRD ABUNDANCE TRENDS IN NORTHERN AND SOUTHERN CCLME.

Even within this sample data set, dozens of seabird species were available for examination. We chose to present data from three seabird species common to all three CCLME domains, and where population density at sea has been already examined in peer-reviewed literature. Those species are common murres (*Uria aalge*), sooty shearwaters (*Puffinus griseus*), and Cassin's auklet (*Ptychoramphus aleuticus*).

During spring and summer, the two numerically dominant seabirds on the continental shelf in all domains of the CCLME are common murres and sooty shearwaters (southern domain: Hyrenbach and Veit (2003); central domain: Ainley and Hyrenbach (2010); northern domain: Zamon et al. (2013), Ainley et al. (2009)). Murres are breeding residents in the CCLME, whereas the shearwaters migrate from the southern hemisphere to the CCLME during their austral winter before returning south in October to breed in Chile and New Zealand. Murres and shearwaters are piscivorous divers, feeding on coastal pelagic species such as anchovy (*Engraulis mordax*), smelt (Osmeridae), sandlance (*Ammodytes hexapterus*), herring (*Clupea pallasii*) and sardine (*Sardinops sagax*), but they will also occasionally consume krill (Euphausiidae) or other invertebrates (e.g. gammarid amphipods). Cassin's auklet is a breeding resident commonly found in all domains of the CCLME, but Cassin's auklets are planktivorous shallow-diving birds, and therefore depend on a different trophic level (krill and plankton) than murres and shearwaters (coastal pelagic fishes). Time series plots of at-sea densities for these three species are shown in Figures SB1, SB2, and SB3.

The long-term average density of murres was greater in the northern domain of the CCLME, which is what one would expect given that murres are considered to be associated with colder water masses (Figure SB1, c.f. Hyrenbach and Veit (2003)). Both domains showed increasing or stable densities. This pattern of stable or increasing densities in murres is similar to that seen in the central domain for a less recent time period (Ainley and Hyrenbach 2010).

The long-term average density of shearwaters was similar in both northern and southern domains, and showed neither an upward nor downward trend in this data set (Figure SB2). This contrasts with results from several prior studies of less recent data, which all showed downward trends in shearwater abundance

from the central and southern CCLME domains (Veit et al. 1996, Hyrenbach and Veit 2003, Ainley and Hyrenbach 2010). The change in trends for sooty shearwaters could be due to changes in shearwater distribution within the CCLME (e.g. a shift to the northern domain) , changes in productivity of coastal pelagic fishes (e.g. McClatchie et al. this report; Brodeur et al. (2005), changes in shearwater reproductive productivity in the southern hemisphere (Lyver et al. 1999), or a combination of all three factors. However, it is clear there has been change in the previous trend of decline in the CCLME.

Both densities and trends for Cassin's auklet density were highly variable (Figure SB3). There appears to be an increasing trend in auklet abundance for the northern CCLME, but decreasing or stable trends for auklets in the southern CCLME. A lack of increasing trends in the southern CCLME is consistent with observations and inferences from earlier years attributing declines in this species to shifts in ocean plankton production associated with ocean warming in central and southern CCLME domains (Hyrenbach and Veit 2003, Ainley and Hyrenbach 2010).

Although we did not have access to data from time series for the central CCLME, Ainley and Hyrenbach (2010) recently published an analysis of data from that region. They observed somewhat similar patterns in the older data: declines in murre and shearwaters followed by an apparent return to higher densities in 2005 and 2006, but historically low densities of Cassin's auklets.

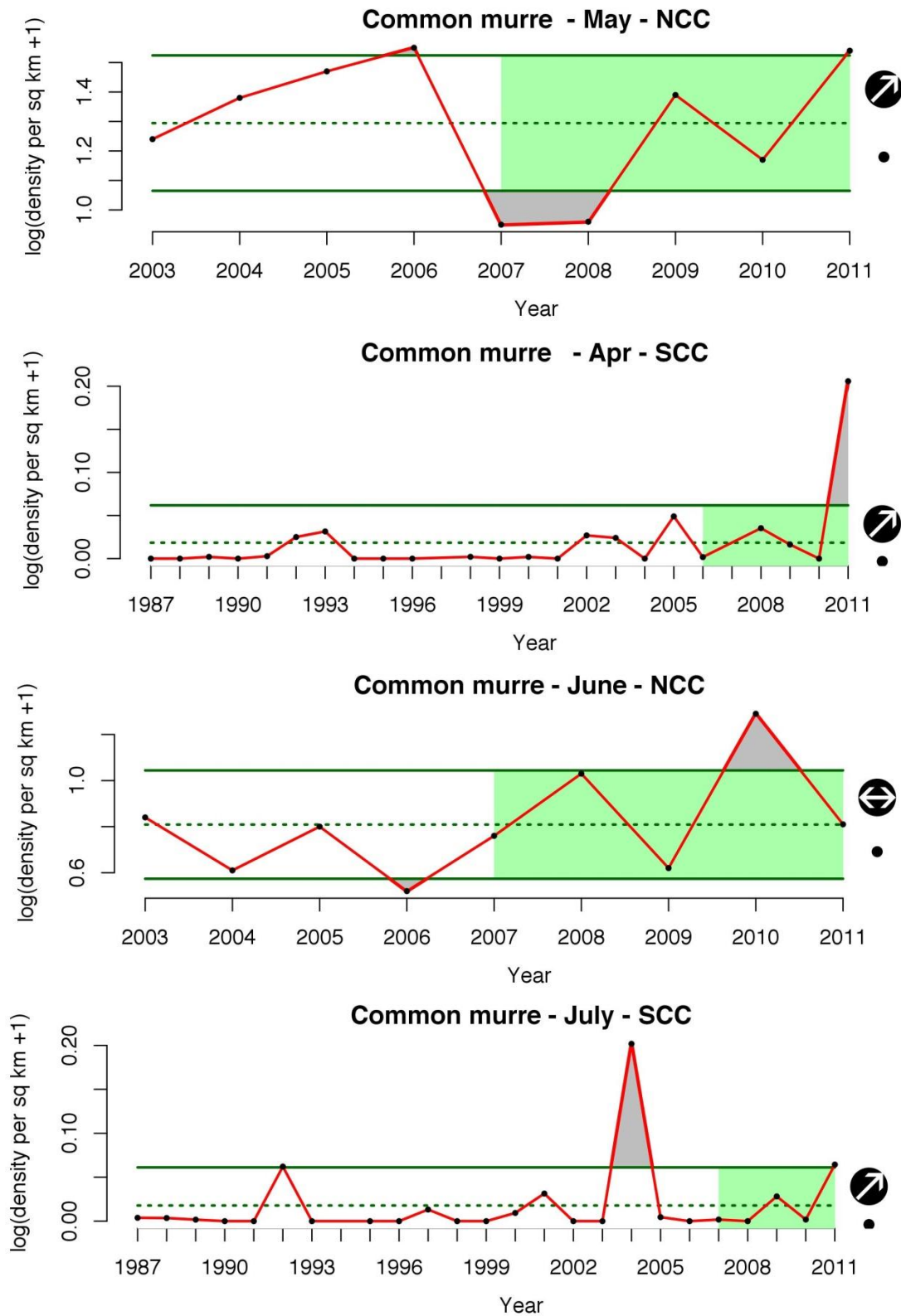


Figure SB1. Trends in seabird density (birds km²) over time for common murres in the northern (NCC) and southern (SCC) domains of the California Current.

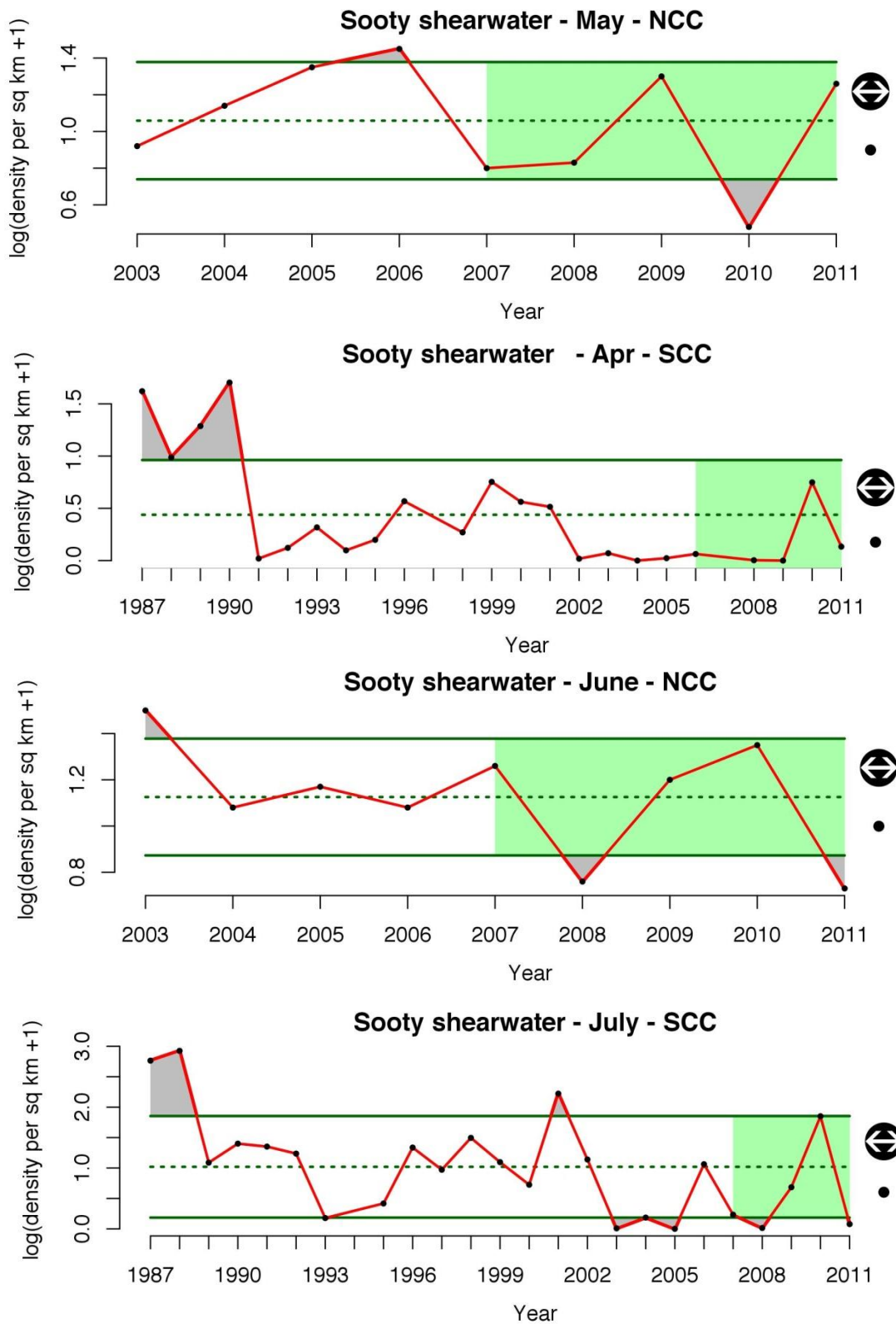


Figure SB2. Trends in seabird density (birds km²) over time for sooty shearwaters in the northern (NCC) and southern (SCC) domains of the California Current.

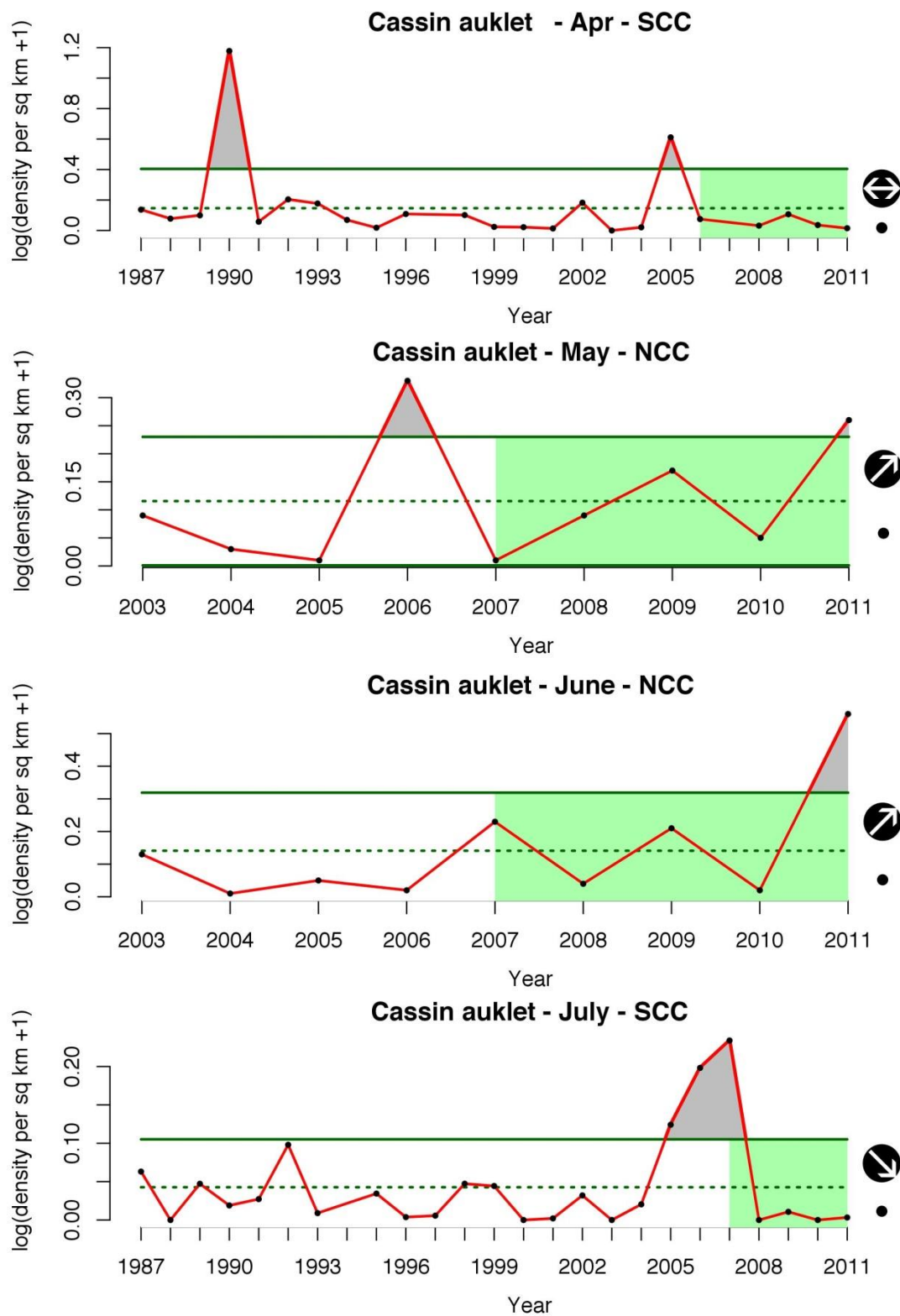


Figure SB3. Trends in seabird density (birds km²) over time for Cassin's auklet in the northern (NCC) and southern (SCC) domains of the California Current

RISK ASSESSMENT – SEABIRDS (FUTURE WORK)

Risk factors known to include at least the following:

- habitat reduction or disturbance on land (breeding birds)
- predation at colonies (breeding birds)
- commercial fishing
 - direct impacts of mortality as bycatch
 - indirect impacts to recruitment
- climate change effects on food web
 - prey species composition
 - timing, duration of prey species productivity
 - harmful algal blooms
 - direct effects of injury/mortality due to removal of waterproofing from plumage
 - indirect effects of bioaccumulation of toxins in prey
- pollution/contaminants/oil spills
- ocean energy development
 - direct effects of collisions, entanglement
 - indirect effects on prey distribution or food web structure

DATA LINKS

SEABIRD INDICATOR DATA USED IN FIGURES

Data credits for this document are as follows:

CCLME northern domain

- Ocean Ecosystem Survey, 2003-present
- NOAA Fisheries - Northwest Fisheries Science Center, Fish Ecology Division.
- This is a multi-investigator ecosystem survey for which seabird data were added as an ecosystem component in 2003. The original time series began in 1998 in response to collapse of Pacific salmon populations in the Columbia River system. The historical purpose of these surveys has been to understand how variation in physical and biological ecosystem components affects early marine growth and survival of juvenile salmon.
- Links to ocean program pages: <http://www.nwfsc.noaa.gov/research/divisions/fed/estuarine.cfm>
- Seabird data contact: Jeannette E. Zamon, jen.zamon@noaa.gov, 503-861-1818 x19

CCLME southern domain

- California Cooperative Oceanic Fisheries Investigations (CalCOFI), 1987-present
- This is a multi-agency, cooperative effort among NOAA Fisheries – Southwest Fisheries Science Center, Scripps Institution for Oceanography, and the California Department of Fish and Game. Seabird data were added as an ecosystem component in 1987. The original time series began in 1949 in response to the collapse of the sardine fishery in California. The historical purpose of these surveys has been to understand how variation in physical and biological ecosystem components affect recruitment processes for sardine and anchovy.
- Link to CalCOFI home page: <http://www.calcofi.org>
- Link to underway observation data pages: <http://www.calcofi.org/field-program/field-under.html>
- Seabird data contact: William J. Sydeman, wsydeman@faralloninstitute.org, 707-478-1381

CONTEMPORARY SEABIRD INDICATOR DATA SOURCES

Existing data sets which can contribute to the IEA are independently maintained by multiple agencies, institutions, and individuals. It was beyond the scope of the 2012 IEA effort to request, screen, format, and integrate data from all of these data sets. However, to facilitate future integration and synthesis of seabird indicators for the CCLME IEA, we provide a list of data programs and contacts presently collecting multi-year indicator data in the CCLME in Table SB2.

The majority of these programs do not have the resources to maintain continuous, long-term time series, but many have information from the past five years or access to discontinuous historical data which might be used for evaluating changes in seabird indicators.

REFERENCES CITED

This bibliography includes all the references the Seabird Subgroup consulted to perform that matrix evaluation process leading to the choice of the final five seabird indicators. It also includes any references cited in the text that were not also included in the evaluation process.

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